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No. 23. ON THE VARIATION OF THE MAGNETIC ACTIVITY AT GODHAVN

BY

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CHARLOTTENLUND
1958

Gift of Meteorologisk Institut, Charlottenlund, Denmark.

L'Institut Météorologique Danois, qui est chargé de l'administration scientifique des travaux magnétiques terrestres en Danemark, publie dans sa publication « Magnetisk Årbog (Annuaire magnétique) » les observations régulières des trois observatoires magnétiques danois, savoir

Rude Skov $\lambda = 12°27'.4$ E, $\varphi = 55°50'.6$ N.
Godhavn $\lambda = 53°31'.3$ W, $\varphi = 69°14'.4$ N.
et *Thule* $\lambda = 69°10'$ W, $\varphi = 77°29'$ N.

En outre l'Institut réunit dans sa publication « Communications Magnétiques, etc. » les mémoires et les extraits des archives des trois observatoires qu'on juge utile de publier.

La série « Communications Magnétiques, etc. », paraît par occasion.

Karl Andersen
Directeur.

L'INSTITUT MÉTÉOROLOGIQUE DANOIS
COMMUNICATIONS MAGNÉTIQUES, ETC. NO. 23

ON THE VARIATION OF THE MAGNETIC ACTIVITY AT GODHAVN.

Abstract:

The magnetic activity at Godhavn has been studied by means of K-indices for the period 1944-55. The activity is composed of two main types. One type, named J, which has its maximum in the forenoon is shown in its average variation through the day and the year to follow the sun. The daily variation has its maximum at local magnetic noon; the yearly distribution has its maximum at summer solstice. In the course of the solar cycle the daily mean value increases with increasing planetaric activity, A_p, whereas the amplitude of the daily variation follows the sunspot number R.

The second type of activity, named N_T, which has its maximum in the evening, is most dominant in the years near sunspot minimum. Its variation through the sunspot cycle is controlled by R, being nearly opposite in phase to R. It is concluded that (the inner border of) the zone of maximum N - (and auroral-) activity is nearest to the magnetic pole in sunspot minimum years.

1. Introduction.

The magnetic activity on the polar side of the auroral belts was first studied by Chree (1915,1927), who from the magnetic records from the Antarctic stations Cape Evans and Cape Denison found that the total activity here decreases from summer through equinox to winter and that the diurnal distribution of the activity shows two maxima and two minima. After the Second International Polar Year, Stagg (1935) showed that the diurnal distribution of the activity is controlled by local time in such a manner that stations with geomagnetic latitude less than about 70° have a diurnal distribution with a minimum around local noon and a maximum around local midnight, whereas stations with magnetic latitude larger than about 80° have a maximum in the forenoon and a minimum at midnight. Stations in the belt $70° < \phi_m < 80°$, which Stagg called the "transitionzone", have a diurnal distribution with two maxima and two minima which can be regarded as a combination of the two main types.

On the basis of material from a larger number of stations Nikolsky (1947) criticized the zonal boundaries determined by Stagg, showing that the boundaries are not lying at the same geomagnetic latitudes in the eastern and western hemispheres. At the same time he showed that the magnitude of the two daily maxima partly vary after dual laws, so that the two types of distributions presumably represented two different types of magnetic activity, possibly due to different types of particles.

Both Stagg and Nikolsky used observations made at widely separated periods. An eventual variation in the zonal boundaries, e. g. in the course of the sunspot period, may have introduced errors in the found results, and it is therefore

necessary either to know the variation of the activity with time or to compare observations made at the same epoch.

The last mentioned method was used by Mayaud (1956), who compared K-indices from a large number of stations from the Second International Polar Year. Mayaud showed that the zonal boundaries are uniquely determined by the inclination at a height of 5000 kms above the earth. Furthermore he showed that the type of activity having its maximum at night, which he calls N, has a yearly distribution different from that of the type of activity with a maximum in the forenoon, which he calls J. N has maxima at the equinoxes and minima in summer and winter, whereas J decreases from summer through equinox to winter.

Finally Mayaud found that J and N are increasing from sunspot minimum to sunspot maximum. As a parameter he, instead of the normally used sunspot number R, used the index A_p, which is a measure of the planetaric activity, and which Mayaud assumes positively correlated with R. Being computed from the K-indices from a number of observatories lying to the south of the northern auroral-zone, A_p is in reality a measure of activity of type N, and Mayaud's results therefore show that J and N are simultaneously increasing; they are positively correlated with the sunspot number, provided that A_p is so. However, the correlation between R and A_p is not always good; thus in the winters 1944-54 the correlation coefficient is only +0,12, and it is mainly for these years that Mayaud has examined the variation of J at Thule and Godhavn.

As, moreover, Mayaud's examinations of the variation of N through the sunspot period mainly relate to observatories on the equatorial side of the "transitionzone",

it is the intention to try in the following to round off the hitherto found results with a description of the variations through the years 1944-55 of the magnetic activity at Godhavn (ϕ_m = 79°8), a station situated in the northern part of the northern "transitionzone".

As a measure of the magnetic activity K-indices for all days have been used. The mean-activity has been determined by formal derivation of the mean of the K-values. GMT has been used; local mean time for Godhavn is GMT÷$3^h 34^m$.

For each of the three seasons winter (NDJF), summer (MJJA) and equinox (MASO) the diurnal distribution of the magnetic activity is first examined. As already mentioned, this consists of two distributions; after Mayaud the distribution with forenoon-maximum is named J, whereas the distribution with maximum at night is named N_T (where the index T refers to "transitionzone"). The variation of the distributions with the sunspot cycle is sought for each season, and finally the variation of the distribution with the season is sought.

2. Winter-activity.

Table 1 gives the mean of K for each of the eight three-hour-intervals of the winters 1943/44 to 1955/56. The horizontal columns of the table thus give the daily distribution for every single winter. These distributions are graphically represented in figure 1. The distributions have two maxima, one in the forenoon, due to J, and one in the evening, due to N_T; the latter is relatively less in years with many than in years with few sunspots.

Table 1. Means of K-values, winters 1943/44 - 1955/56.

GMT / Year	0 - 3 K_1	3 - 6 K_2	6 - 9 K_3	9 - 12 K_4	12 - 15 K_5	15 - 18 K_6	18 - 21 K_7	21 - 24 K_8	mean K_{3-7}	$K_1 : K_{3-7}$	A_p mean(γ)	R smoothed
1943/44	3,17	2,48	2,54	3,04	3,16	3,06	2,46	2,73	2,87	1,14	29 1/2	8,6
44/45	2,72	2,31	2,44	2,76	2,80	2,71	2,24	2,04	2,59	1,05	20	20,3
45/46	2,83	2,74	2,88	3,02	3,17	2,94	2,59	2,49	2,92	0,97	28	59,4
46/47	2,24	2,11	2,28	2,72	2,94	2,80	2,13	1,97	2,57	0,87	23	128,6
47/48	2,50	2,45	2,50	2,90	3,21	2,94	2,45	2,32	2,80	0,89	25	146,7
48/49	2,65	2,56	2,68	2,91	3,22	3,05	2,52	2,50	2,88	0,92	32	138,6
49/50	2,63	2,48	2,53	2,88	3,26	3,05	2,54	2,30	2,85	0,92	27	115,5
50/51	3,42	3,01	3,03	3,21	3,62	3,42	3,16	3,05	3,29	1,04	37	72,4
51/52	3,57	3,33	3,15	3,61	3,77	3,54	2,98	3,32	3,41	1,05	41 1/2	48,4
52/53	3,32	2,83	2,82	3,28	3,34	3,16	2,57	2,62	3,03	1,10	28 1/2	24,9
53/54	3,24	2,80	2,72	3,18	3,28	2,97	2,46	2,61	2,92	1,11	22 1/2	6,9
54/55	2,78	2,47	2,48	2,91	3,03	2,87	2,19	2,20	2,70	1,03	19 1/2	10,8
55/56	2,68	2,69	2,78	2,96	3,25	3,06	2,52	2,42	2,91	0,92	25 1/2	90,1

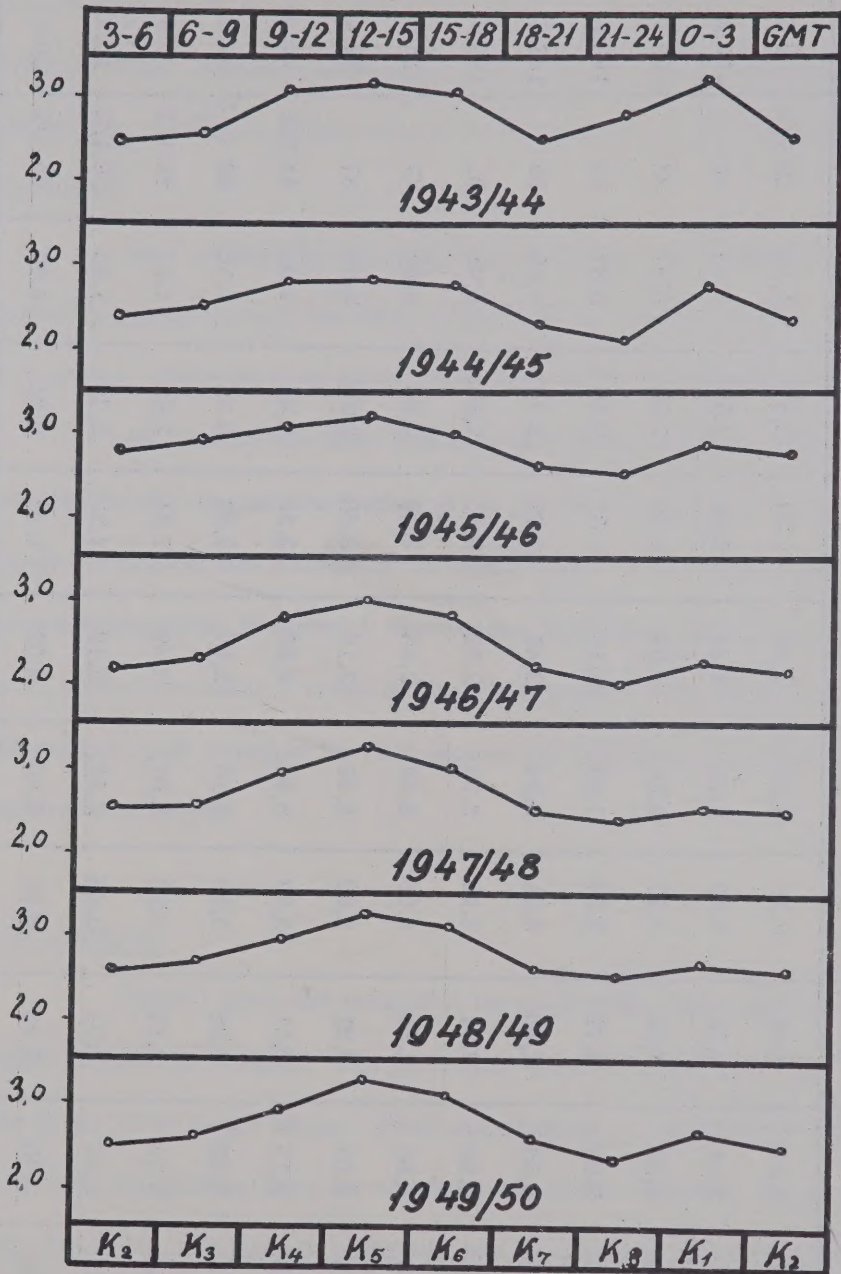

Fig. 1a. Diurnal distributions of mean magnetic activity winters 1943/44 - 1949/50.

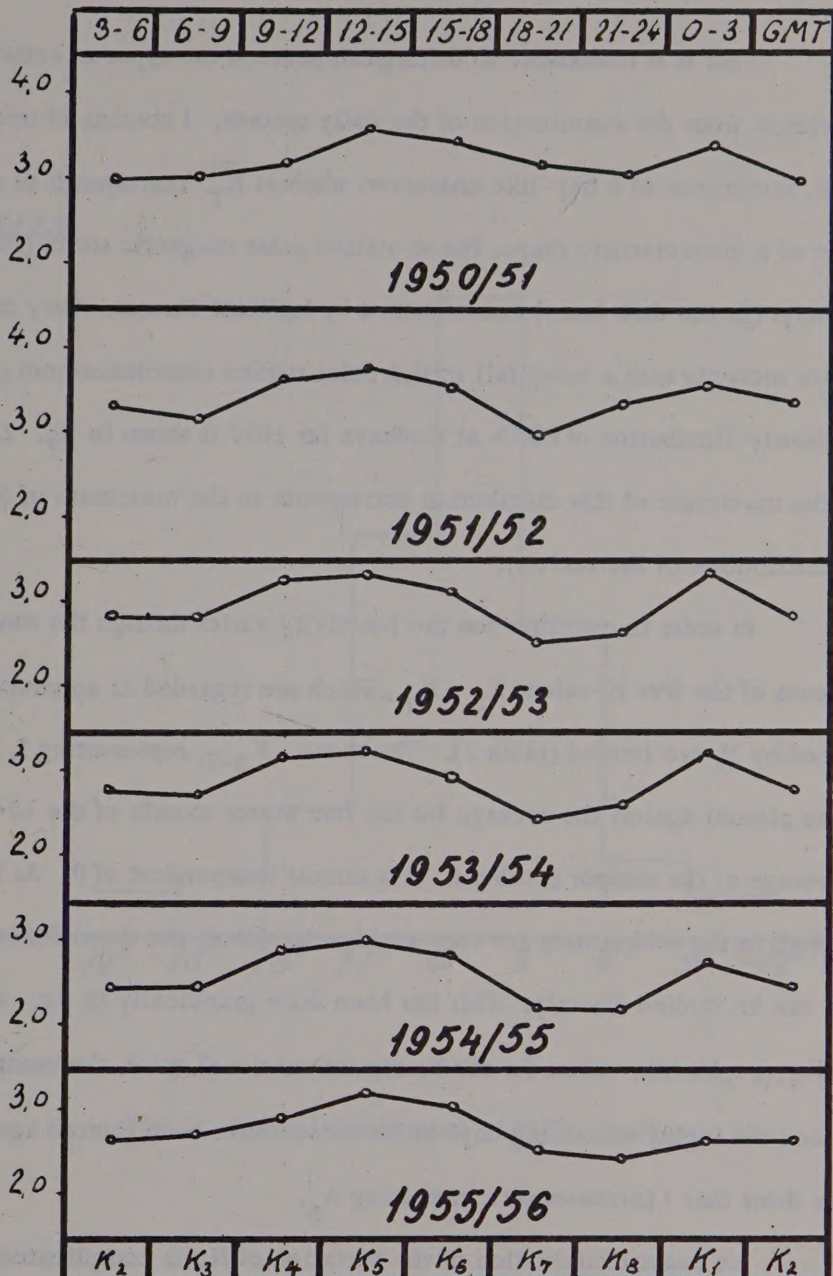

Fig. 1b. Diurnal distributions of mean magnetic activity winters 1950/51 - 1955/56.

That it is reasonable to distinguish between two types of activity is an experience from the examination of the daily records. J consists of irregular oscillations, sometimes of a bay-like character, whereas N_T corresponds to a bay-disturbance of a characteristic shape, the so-called polar magnetic storm (PMS), which is always (in the dark hours) accompanied by brilliant auroras. Very often such a bay begins suddenly with a steep fall in H, a polar sudden commencement (PSC). The three-hourly distribution of PSC's at Godhavn for 1950 is shown in fig. 2. It is seen that the maximum of this distribution corresponds to the maximum of N_T in the daily distribution of the activity.

In order to examine how the J-activity varies through the sunspot period, means of the five K-values K_3 - K_7, which are regarded as approximately uninfluenced by N, are formed (table 1). The mean, K_{3-7}, representing J, has in fig. 3 been plotted against the average for the four winter months of the 13-month running average of the sunspot number R. J is almost independent of R. As R and A_p, as mentioned, in the said winters are very weakly correlated, the dependence of J on A_p alone can be studied directly. This has been done graphically in fig. 4 where the values of K_{3-7}, split into values for the twenty international quiet, the twenty international disturbed and the eighty remaining days of the season have been plotted against A_p (table 2). The figure shows that J increases with increasing A_p.

An exact examination of the variation of N_T is complicated by the impossibility of a complete separation of N_T and J. K_1 is presumably dominated by

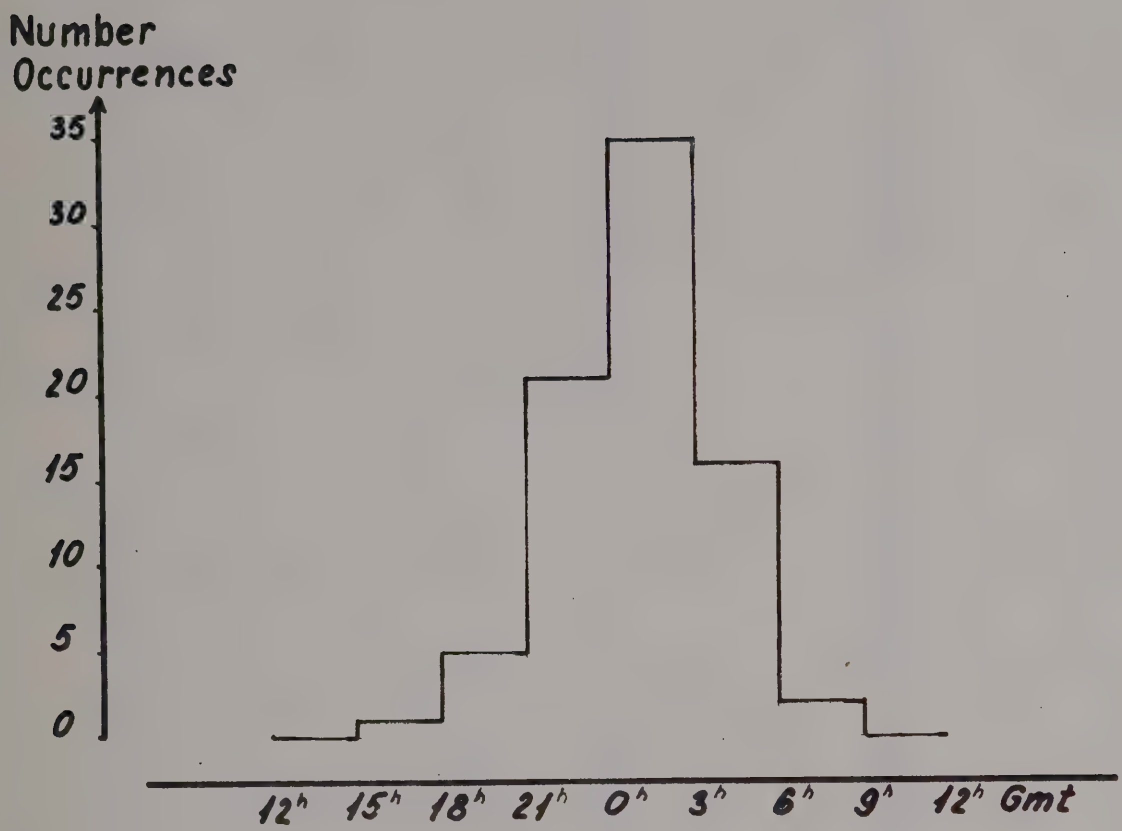

Fig. 2. Diurnal distribution of PSC's, Godhavn 1950.

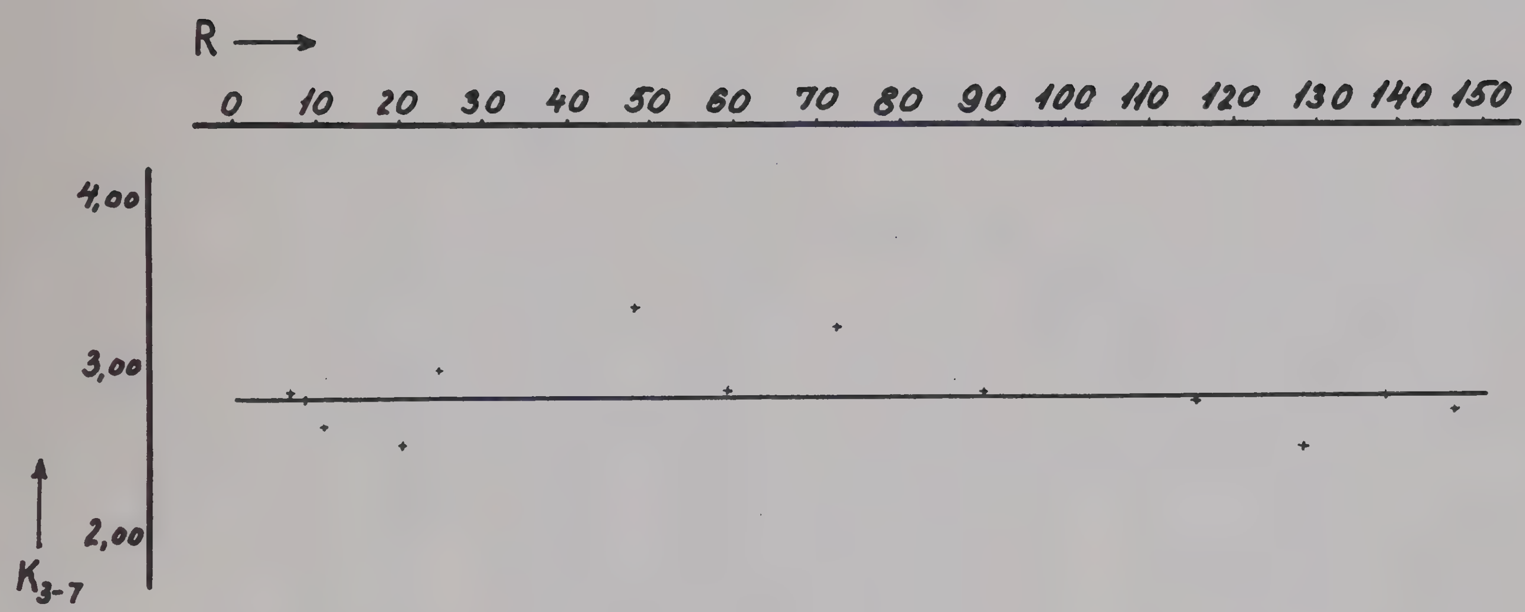

Fig. 3. K_{3-7} (~J) vs. R, winter.

Table 2. Means of K-values, international quiet, disturbed and remaining days.

NDJF		1943/44	1944/45	1945/46	1946/47	1947/48	1948/49	1949/50	1950/51	1951/52	1952/53	1953/54	1954/55
q	$A_p\gamma$	7,3	5,4	6,5	6,2	7,6	8,6	7,9	9,8	10,6	7,1	7,6	4,6
	K_1	1,55	1,70	1,95	0,90	1,60	1,44	2,10 x)	2,42 x)	1,89	1,95	2,20	1,90
	K_{3-7}	1,84	1,76	2,15	1,59	2,01	1,95	2,12	2,40	2,50	2,13	2,31	1,70
	$K_1 : K_{3-7}$	0,84	0,965	0,91	0,565	0,795	0,74	0,99	1,01	0,755	0,915	0,95	1,12
d	$A_p\gamma$	70,2	54,3	81,9	52,8	53,9	85,2	66,9	79,1	86,4	70,2	49,8	34,2
	K_1	5,00	3,55	3,75	2,70	3,35	3,54 x)	3,05	4,52	4,57 x)	4,75 x)	4,75	3,70
	K_{3-7}	3,99	3,57	3,98	3,57	3,68	3,83	3,65	4,11	4,02	4,02	3,74	3,28
	$K_1 : K_{3-7}$	1,255	0,995	0,94	0,755	0,91	0,925	0,835	1,10	1,14	1,18	1,27	1,13
r	$A_p\gamma$	25,9	15,1	19,9	19,8	22,1	25,0	21,8	33,3	38,0	23,4	19,4	19,5
	K_1	3,12	2,77	2,82	2,46	2,51	2,75	2,76	3,48	3,78	3,34	3,12	2,77
	K_{3-7}	2,85	2,55	2,85	2,56	2,78	2,88	2,83	3,31	3,48	3,01	2,87	2,54
	$K_1 : K_{3-7}$	1,095	1,085	0,99	0,96	0,89	0,955	0,975	1,05	1,085	1,11	1,085	1,09

x) the table here gives K_8 which is slightly larger than K_1.

N_T, but it is not out of the question that there may be an appreciable J-component in K_1, and it is therefore hardly permissible to examine N_T by a method analogous to that used in the study of J. Instead the following procedure was tried: Tentatively K_1 was plotted as a function of A_p. Apparently K_1 increases with increasing A_p, but there is not a one-to-one relation. A provisional examination shows that K_1 is better controlled by R; there is, however, a rather great scattering, probably in consequence of a simultaneous dependence on A_p. The scattering is essentially reduced if the proportion K_1: K_{3-7} (representing N_T: J) is examined instead of K_1. Obviously, K_1 and K_{3-7} thus depend in an analogous manner on A_p, so that the influence of A_p is almost eliminated by the formation of the proportion. In fig. 5 K_1: K_{3-7} has been plotted against R. The proportion decreases with increasing R. As K_{3-7} as shown is independent of R, the figure shows that K_1, and consequently N_T, decrease with increasing R.

The variation of $K_1 : K_{3-7}$ through the sunspot period is shown in figure 15a. The proportion is less than its mean value (=1,00) in the years before and around the sunspot maximum, bigger than its mean value in the years before and around the sunspot minimum. The figure shows that N_T varies nearly opposite in phase to the sunspot number, (notice positive direction downwards in fig. 15a).

In order to control the statement that K_1: K_{3-7} is independent of A_p, this proportion has been plotted as a function of A_p for the quiet, disturbed and remaining days of table 2 (fig. 6). In the figure the winters have been separated into two groups,

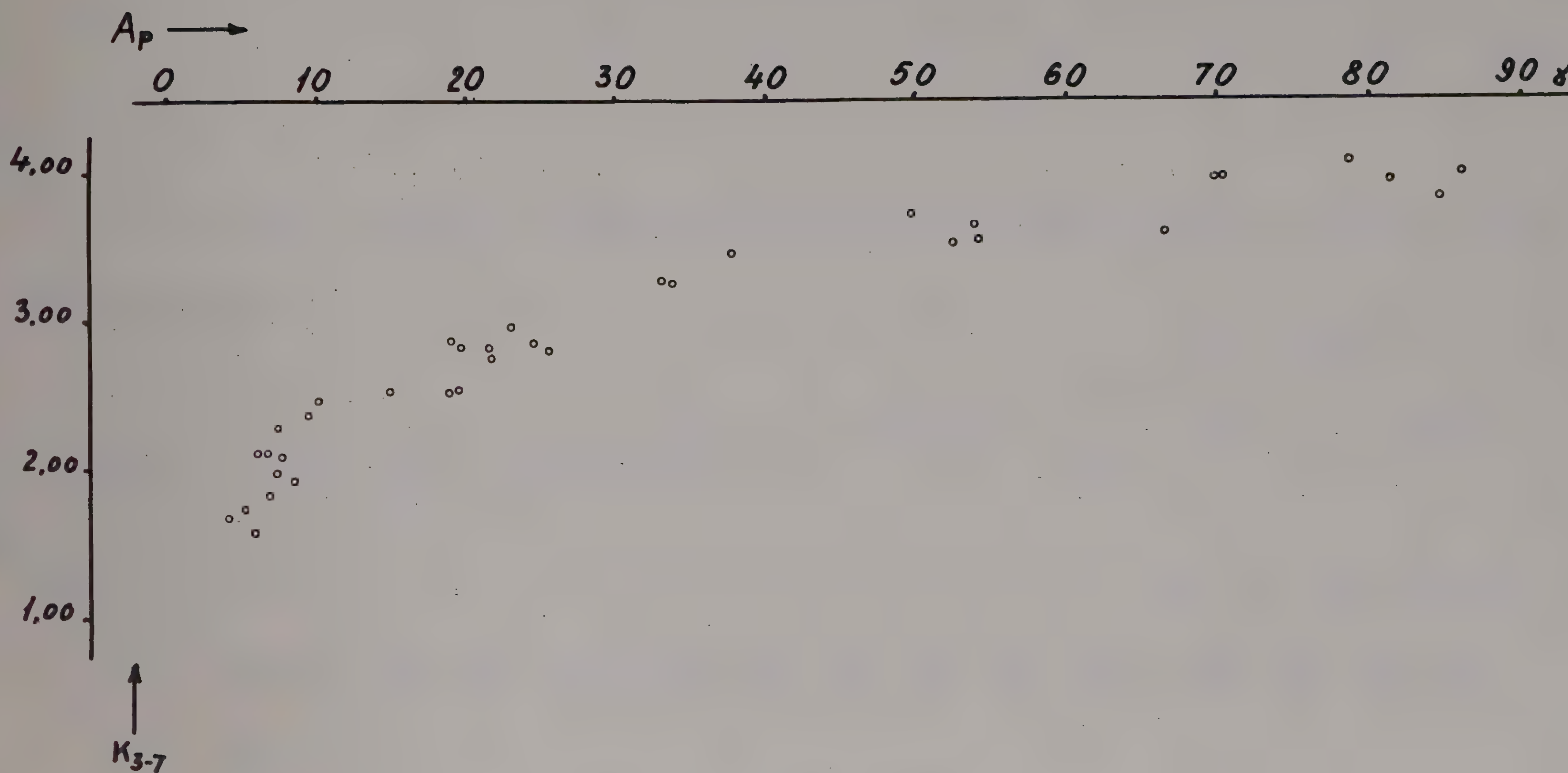

Fig. 4. K_{3-7} (~J) vs. A_p, winter.

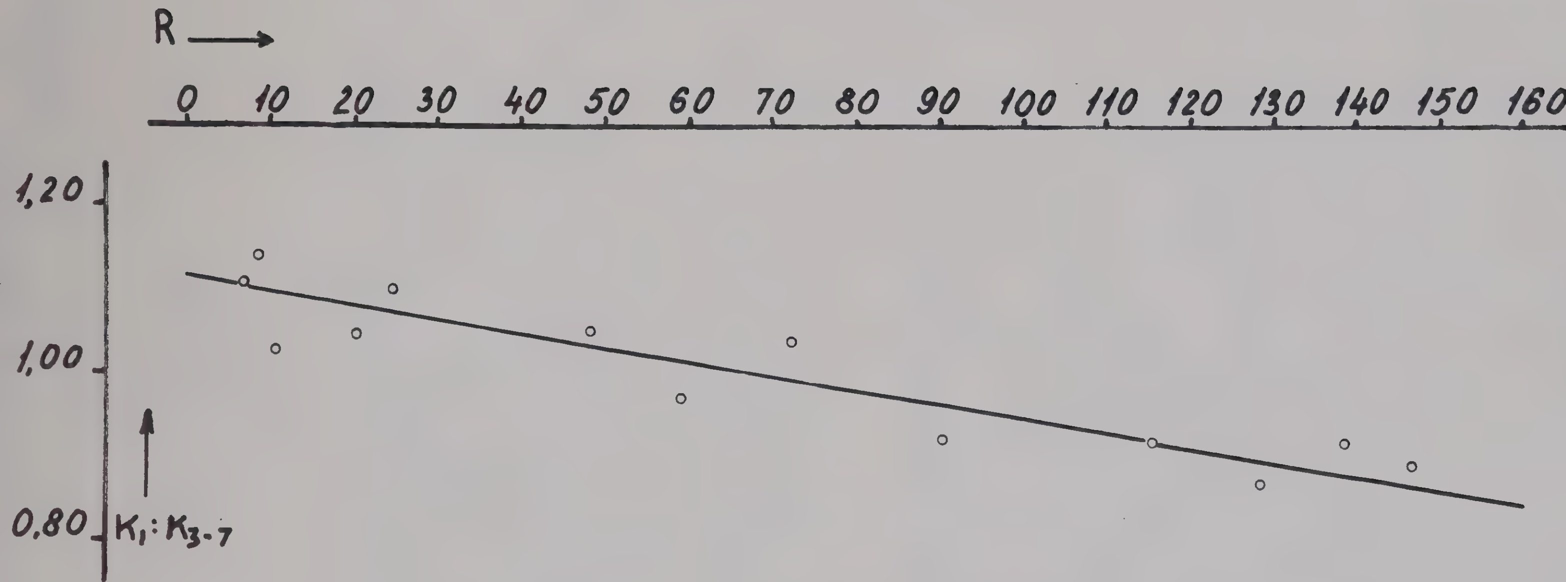

Fig. 5. $K_1 : K_{3-7}$ vs. R, winter.

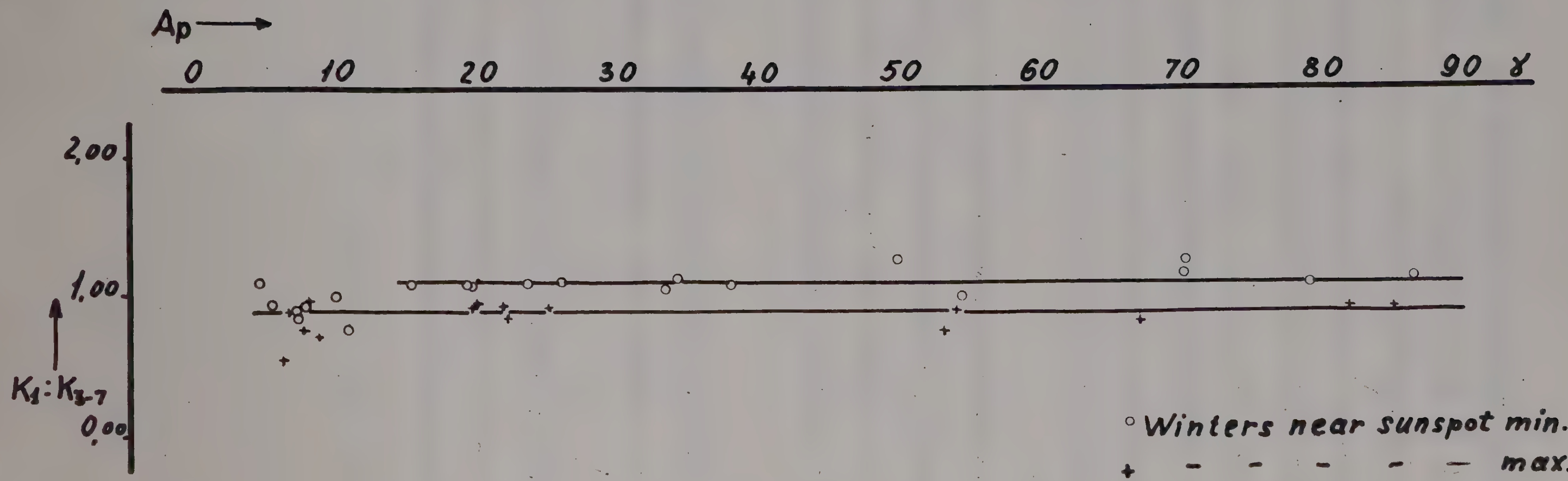

Fig. 6. $K_1 : K_{3-7}$ vs. A_p, winter.

corresponding to $K_1: K_{3-7}$ for all days larger or less than 1,00. Inside each group the means of the values for the quiet, for the disturbed and for the remaining days have been formed. In the sunspot maximum-years these three means are practically identical, and statistical tests (Student's and Welch's tests) show that the differences between them are not significant at the 5% level. For the sunspot minimum-years Welch's test shows that the difference between the mean values of $K_1: K_{3-7}$ for the remaining and the disturbed days is not significant at the 5% level, whereas the difference between the means for quiet and remaining days is significant already at the 1% level. Student's t-test shows that the difference between the means for quiet and disturbed days is significant at the 1/2 0/00 level.

It is hence concluded that in sunspot maximum-years $K_1: K_{3-7}$, and consequently $N_T: J$, are independent of A_p. In sunspot minimum-years $N_T: J$ is independent of A_p for $A_p > 20$; for $A_p < 20$ the value is less in correspondance with the fact that J, as shown by Mayaud (for 1932-33), is present in an appreciable degree even on very quiet days.

3. Summer-activity.

Table 3 gives the mean of K for each of the eight three-hour-intervals of the summers 1944-55. The corresponding diurnal distributions are graphically represented in figure 7.

In the course of the sunspot cycle the distribution curves gradually shift between two types: In the years around sunspot maximum the distribution is a single, twenty-four-hourly wave with maximum near noon and minimum near midnight; in the years before

Table 3. Means of K-values, summers 1944-55.

GMT / Year	0 - 3 K_1	3 - 6 K_2	6 - 9 K_3	9 - 12 K_4	12 - 15 K_5	15 - 18 K_6	18 - 21 K_7	21 - 24 K_8	mean K_{3-7}	A_p mean ♉	R smoothed
1944	2,70	2,50	2,92	3,62	3,88	3,61	2,90	2,75	3,39	16	10,1
45	2,58	2,55	2,91	3,68	3,94	3,96	3,13	2,78	3,52	16	34,5
46	3,19	3,12	3,57	4,26	4,64	4,63	3,85	3,36	4,19	33	91,2
47	3,20	3,12	3,63	4,48	4,93	4,78	4,15	3,57	4,39	36	148,3
48	3,07	2,95	3,47	4,30	4,82	4,69	3,91	3,40	4,24	29 1/2	136,0
49	2,74	2,56	3,23	4,08	4,53	4,40	3,52	3,18	3,95	26 1/2	134,0
50	3,15	2,74	3,16	4,25	4,74	4,56	3,64	3,38	4,07	34 1/2	85,3
51	3,44	3,10	3,54	4,44	4,94	4,86	3,95	3,61	4,35	39 1/2	67,2
52	3,48	3,12	3,25	4,40	4,80	4,36	3,53	3,45	4,07	36 1/2	31,4
53	3,12	2,76	3,14	4,15	4,42	4,10	3,49	3,30	3,86	32	14,0
54	2,72	2,28	2,74	3,60	3,70	3,49	2,96	2,74	3,30	15 1/2	5,3
55	2,60	2,38	2,94	3,84	3,98	3,89	3,19	2,89	3,57	18 1/2	32,0

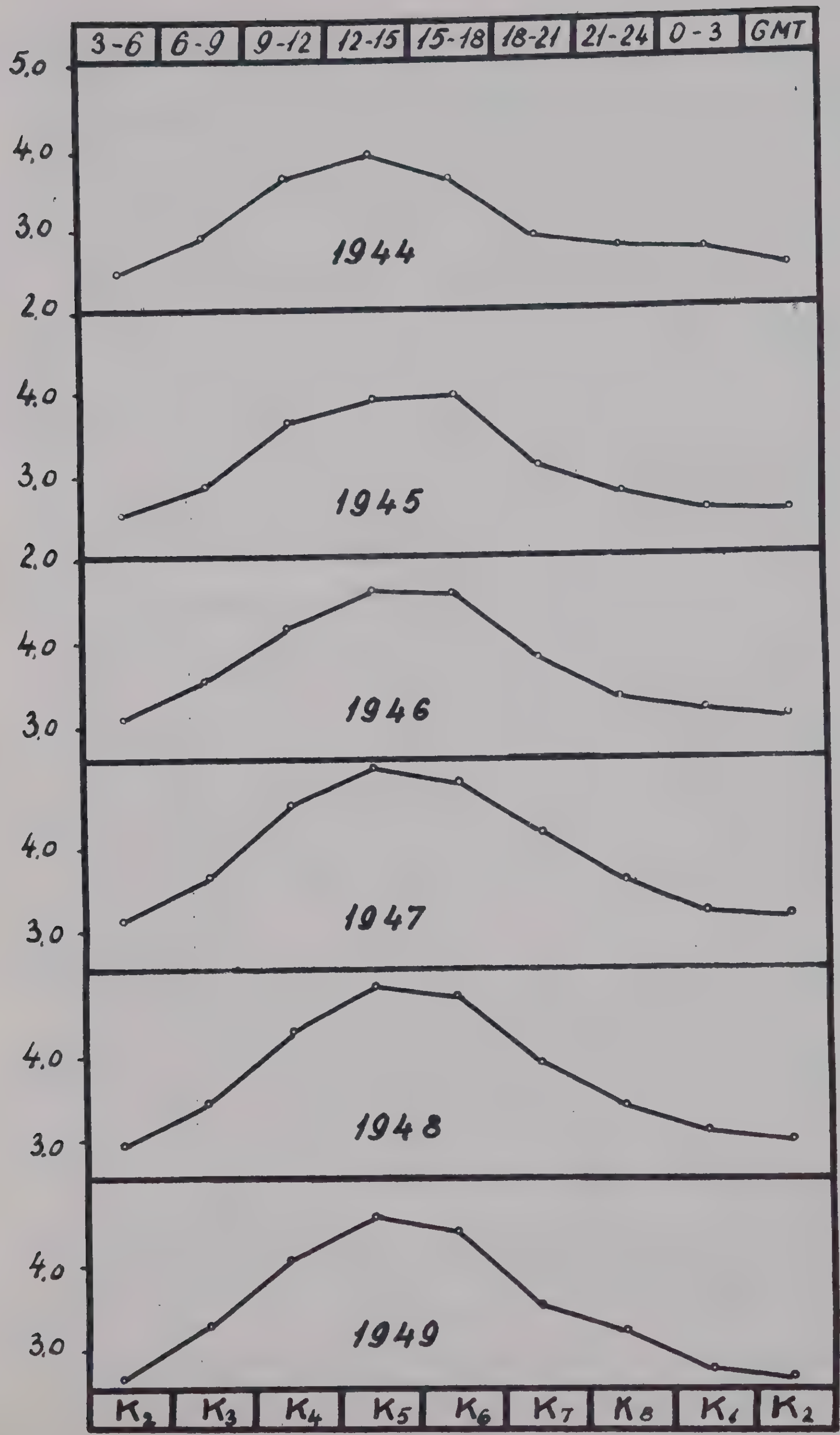

Fig. 7a. Diurnal distribution of mean magnetic activity, summers 1944-49.

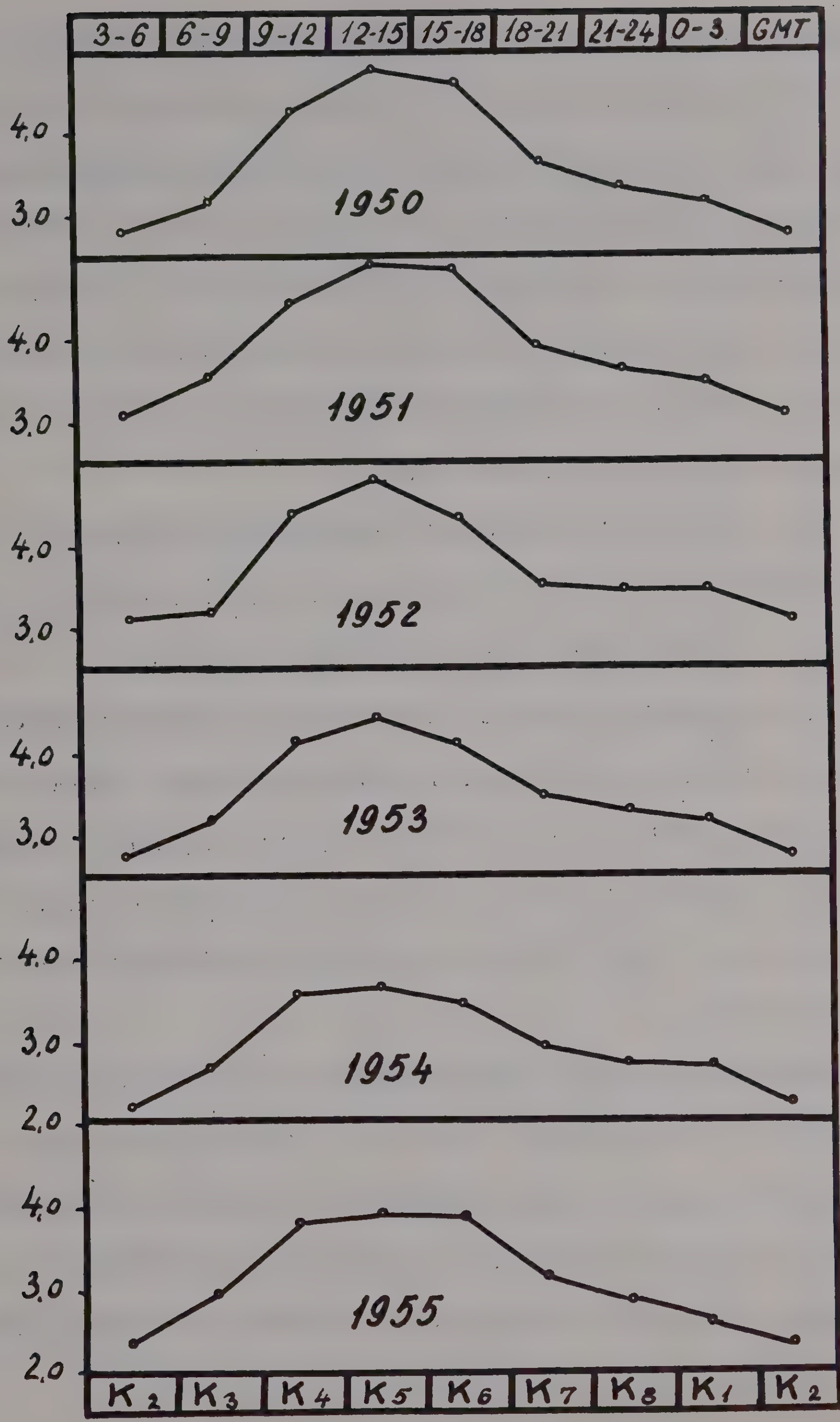

Fig. 7b. Diurnal distribution of mean magnetic activity, summers 1950-55.

sunspot minimum the distribution has a secondary maximum at $0^h - 3^h$ GMT.

The twenty-four-hour wave of the summer is so regular that it is reasonable to examine it further by harmonic analysis. Also the combined distribution at sunspot minimum has been analysed harmonically; the influence of the N_T - distribution will here be reflected in the second harmonic, and the distribution will, by its situation near the minimum of the J-distribution, possibly give a displacement of the computed phase of the first harmonic. The harmonic constants found by analysis of the minimum years should therefore be used with some caution.

The values found by the harmonic analysis are given in table 4. $\overline{K}$ is the mean value of the eight analysed K-values; c_1 and c_2 are the amplitudes of the two first harmonics. The maximum hours are given in local mean time.

At the harmonic analysis the K-values have been regarded as centered in the midpoint of the three-hour-intervals. The analysis show that in sunspot maximum-years the magnetic activity J, represented in this way, is well described by a sinewave with maximum at about $10^h 51^m$ LMT. As, in mean for the summer, magnetic noon at Godhavn is at ab. $11^h 03^m$ LMT, it is seen that the J-distribution is controlled by local magnetic time.

Actually it is no doubt a rough approximation to centre the K-values in the midpoint of the three-hour-intervals. As the mean K-values represent means of maximum deviations, it will, owing to the sinusoidal trend of the distribution, be more correct to place the mean value of K near that end of the three-hour-interval which is nearest to the maximum. However, this is not valied in the maximum-and minimum intervals

Table 4. Results of harmonic analysis of diurnal distributions summers 1944-55.

Year	$\overline{K}$	c_1	max. L. T.		c_2	max. L. T.	
			h	m		h	m
1945	3,19	0,76	10	40	0,13	22	08
46	3,83	0,81	10	46	0,11	22	31
47	3,98	0,93	11	04	0,09	21	10
48	3,83	0,94	11	00	0,13	21	42
49	3,53	0,96	10	54	0,15	20	56
55	3,21	0,80	10	43	0,16	20	24
Mean			10^h	51^m		21^h	28^m
1944	3,11	0,65	10	01	0,20	21	18
50	3,70	0,92	11	09	0,28	21	22
51	3,98	0,85	11	04	0,22	21	56
52	3,80	0,73	10	34	0,39	21	28
53	3,56	0,73	10	51	0,27	20	50
54	3,03	0,62	10	39	0,23	20	39
Mean			10^h	38^m		21^h	16^m

where it is difficult beforehand to estimate where the mean values of K most correctly ought to be placed. If allowance is made for that the K-means ought not to be centered in the midpoint of every interval, c_1 will be modified a little, whereas the phase because of symmetry will be almost unaltered. On the other hand c_2 will probably be appreciably less than the values of table 4 (this presumably without modifying the variation of c_2 with R); the phase is hardly essentially altered.

When the curve thus produced by smoothing of the correctly placed K-values is regarded, it is reasonable to assume that the means of a large number of activity-values, computed for time intervals essentially shorter than three hours, would be approximated by the same sinewave, so that the first harmonic is approximately determining a continuous distribution curve for the magnetic activity of class J. This distribution then follows local magnetic time.

$\overline{K}$ increases with increasing A_p. In fig. 8 the relation between $\overline{K}$ and A_p is shown graphically for each of the two groups of summers of table 4. For the same value of A_p $\overline{K}$ is a little less in doublewave summers than in singlewave summers, although N_T will increase $\overline{K}$ in the firstmentioned summers. If the difference, when further material will be available, appears to be significant the explanation should presumably be sought either in a common "planetaric" variation in the intensity of J through the solar-cycle, or in a shifting in the geographical distribution of the activity.

The variation of c_1 is shown graphically in fig. 9. c_1 varies in phase with R. In order to ascertain whether this result is consistent with that, found for the winters,

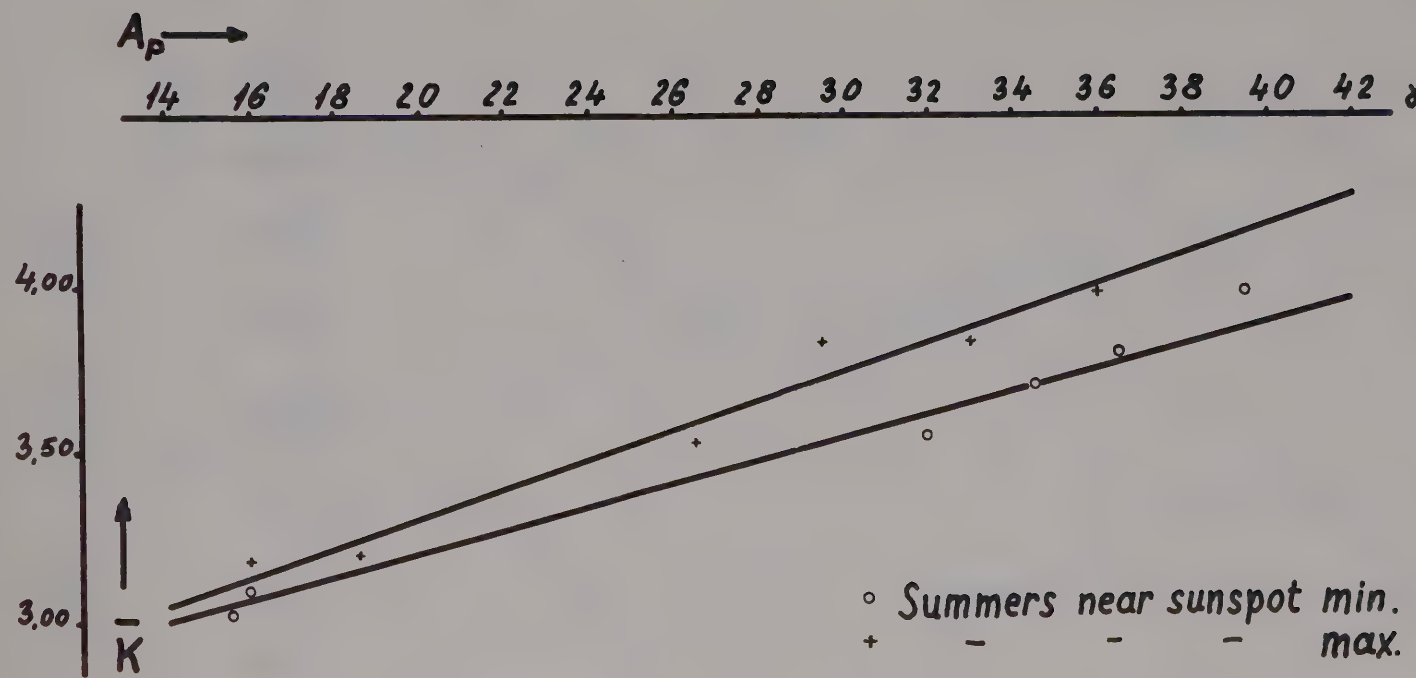

Fig. 8. K vs. A_p, summer.

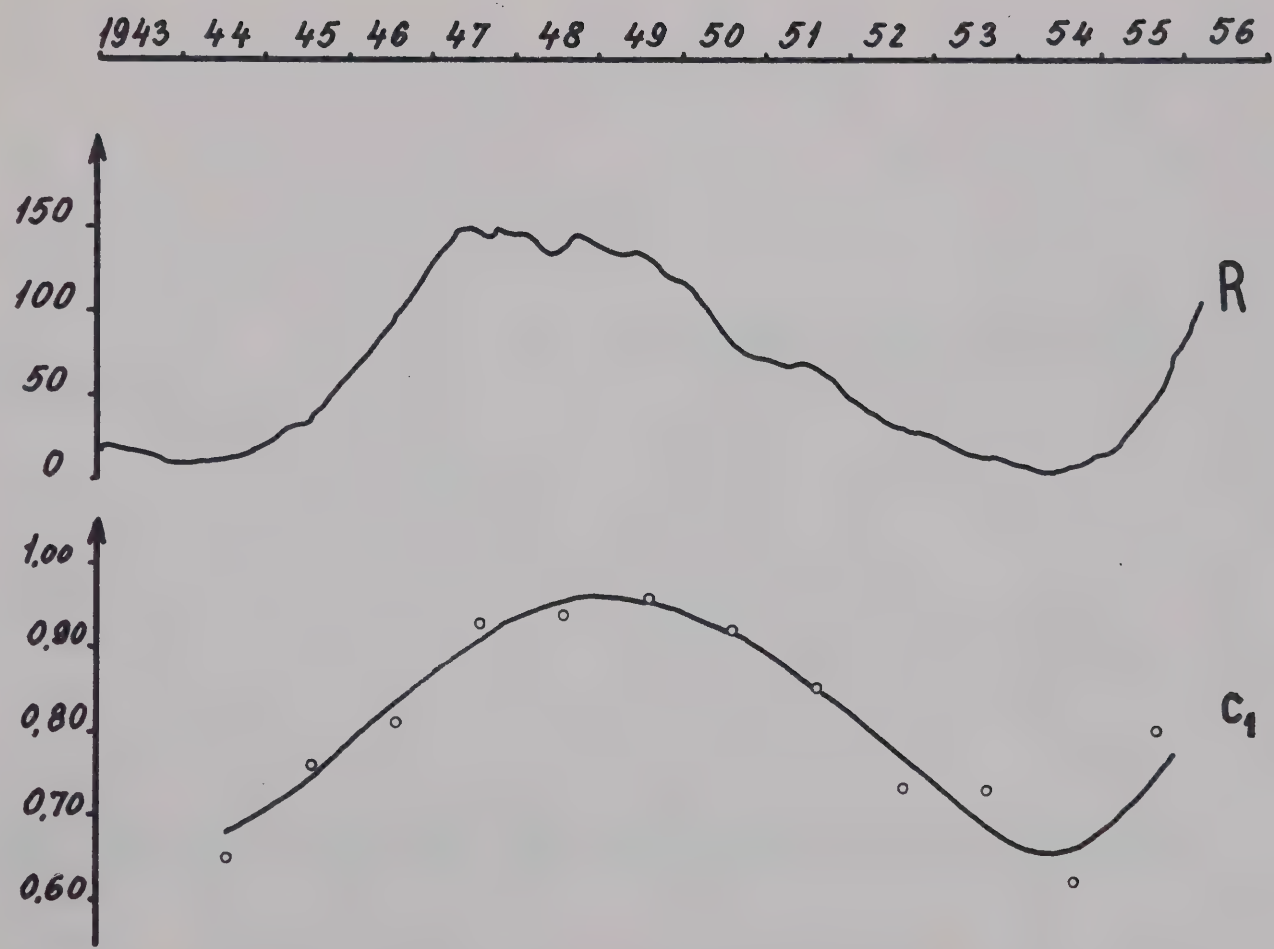

Fig. 9. Variations of c_1 and R, summers 1944-55.

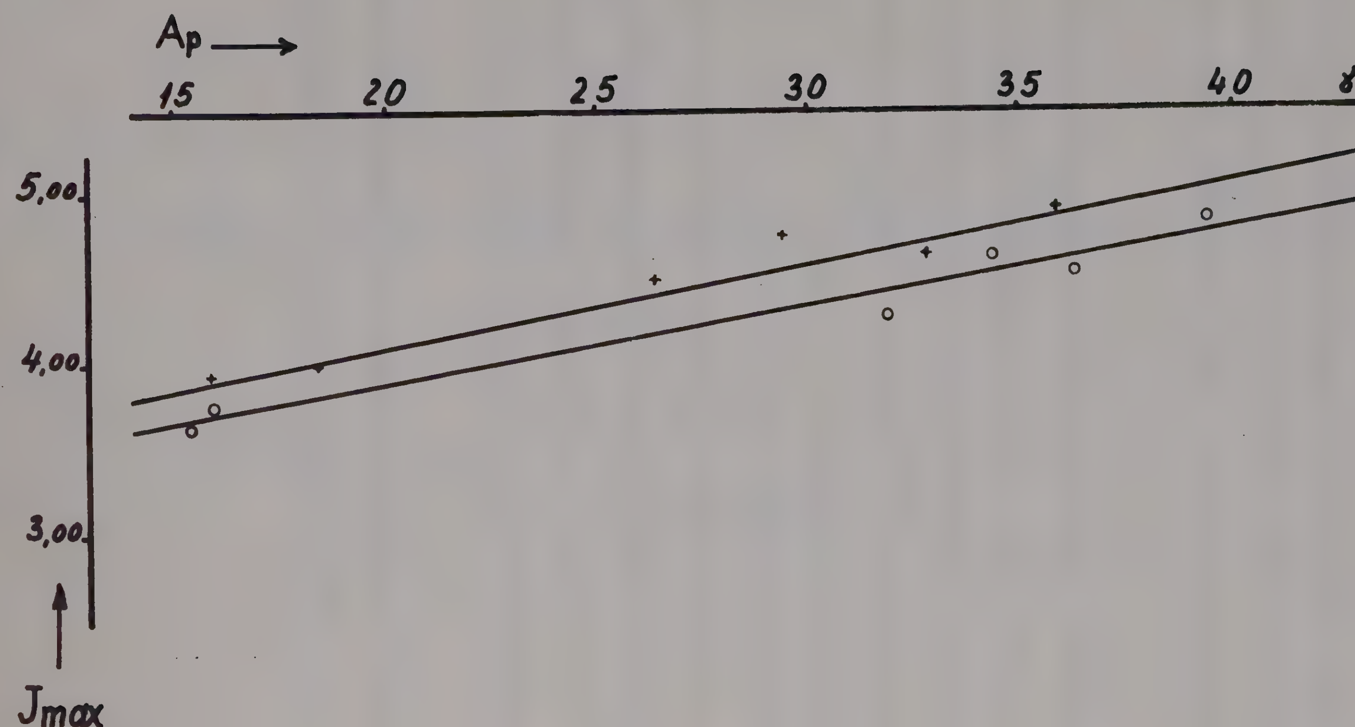

Fig. 10. J_{max} vs. A_p, summer.

namely that J is controlled by A_p, the magnitude of the J-maximum, $\overline{K} + c_1$, is examined. As the variation of $\overline{K}$ is dominating, the magnitude of the maximum also in summer follows A_p (fig. 10).

The J-activity is thus controlled by magnetic time, with its maximum near magnetic noon. The amplitude of the diurnal distribution varies almost in phase with the sunspot number R, whereas the average mean activity of the 24 hours follows the planetaric activity-index A_p.

At the analysis the second harmonic has been thought to be expressive of the influence of N_T (as mentioned, however, part of c_2 originates in the centering of K in the midpoints of the intervals). The average for the years 1944-55 of the time of the maximum has been found to be at $21^h 22^m$LMT ($00^h 56^m$GMT). The deviations from the mean is larger than for the first harmonic.

The variation of c_2 through the sunspot cycle is seen in fig. 15b. c_2 varies in phase opposite to R, so that the extrema of c_2 are situated 1-2 years before those of R; cp. fig. 11 where c_2 has been plotted as a function of the sunspot number R' of the next following summer. As the variation of c_2, as mentioned, is regarded as expressive of the variation of N_T the figure shows that N_T in summer, too, varies nearly opposite in phase to R.

As there is not a linear relationship between the K-value and the disturbance in gammas, the harmonic coefficients ought to be corrected for the departure from

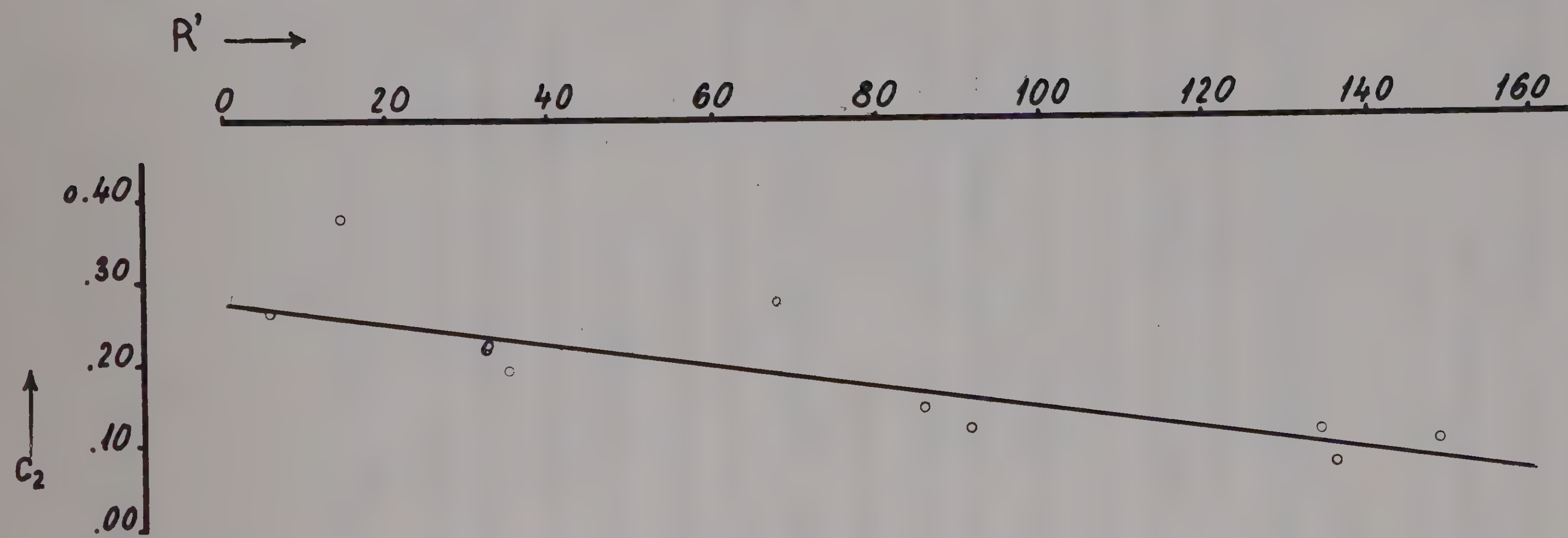

Fig. 11. c_2 vs. sunspot number R' of the next following summer.

linearity. The variation of the mean value of K is, however, so small that K inside the interval may be regarded as a linear function of the disturbance in gammas. The variation of the found coefficients is therefore believed to give an approximately correct picture of the variation of the activity.

4. Equinoctial activity.

Table 5 gives the mean value of K for each of the eight three-hour-intervals of the equinoxes 1944-55. The corresponding diurnal distributions are graphically represented in fig. 12. The distributions are of the same type as the simultaneous summer distributions, but the relative influence of N_T is larger than in these. In consequence, it has been regarded as most correct to refrain from analysing the curves harmonically, as it may be feared that the results will be too much distorted by the presence of N_T near the minimum of J. (Corresponding considerations have been made regarding the winter distributions).

So the J-activity has again been represented by K_{3-7} which from fig. 13 is seen to increase with increasing A_p (there appears to be a slight dependence on R, too but it seems most probable that this dependence should be explained by the correlation between A_p and R (correlation coefficient 0,36)).

N_T has once more been examined by the proportion $K_1 : K_{3-7}$ (fig. 14). The slope of the curve cannot be explained by the mentioned weak dependence of K_{3-7} on R, and hence it is concluded that K_1 decreases with increasing R, so that N_T at the equinoxes, too, is largest in years with few sunspots.

Table 5. Means of K-values, equinoxes 1944-55.

GMT / Year	0 - 3	3 - 6	6 - 9	9 - 12	12 - 15	15 - 18	18 - 21	21 - 24	mean	$K_1 : K_{3-7}$	A_p	R
	K_1	K_2	K_3	K_4	K_5	K_6	K_7	K_8	K_{3-7}		mean γ	smoothed
1944	3,09	2,42	2,66	3,42	3,76	3,41	2,92	2,86	3,23	0,96	27	10,9
45	2,68	2,26	2,52	3,43	3,63	3,48	2,88	2,69	3,19	0,84	25 1/2	36,8
46	3,20	2,75	3,25	3,81	4,25	4,00	3,35	3,10	3,73	0,86	50	90,9
47	2,94	2,78	3,08	3,90	4,69	4,42	3,60	3,17	3,94	0,75	51	145,1
48	2,81	2,66	2,94	3,55	4,11	3,95	3,25	3,04	3,57	0,79	36	144,8
49	2,57	2,33	2,70	3,45	3,91	3,76	3,10	2,63	3,38	0,76	35 1/2	128,6
50	3,14	2,80	3,02	3,64	4,17	3,83	3,24	2,99	3,58	0,88	41	88,9
51	3,82	3,35	3,40	4,28	4,70	4,26	3,65	3,54	4,06	0,94	56	65,0
52	3,61	3,00	3,18	4,00	4,39	4,12	3,44	3,52	3,83	0,94	55	33,0
53	3,24	2,69	3,06	3,63	4,00	3,67	3,07	3,04	3,49	0,93	37 1/2	15,2
54	3,31	2,62	3,08	3,65	3,84	3,59	3,08	3,17	3,45	0,96	31	6,0
55	2,70	2,37	2,84	3,56	3,72	3,47	2,90	2,76	3,30	0,82	26 1/2	29,4

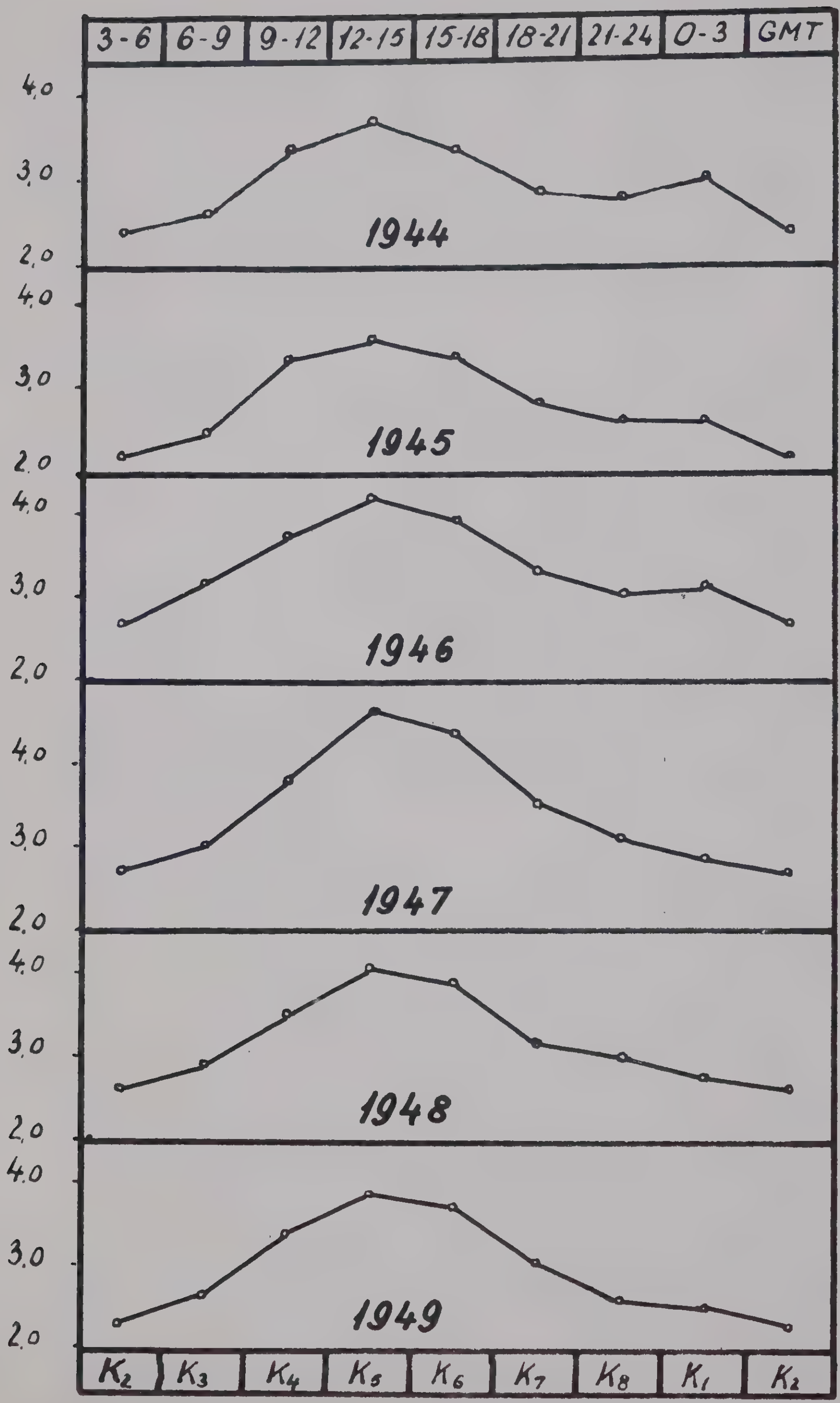

Fig. 12a. Diurnal distributions of mean magnetic activity, equinoxes 1944-49.

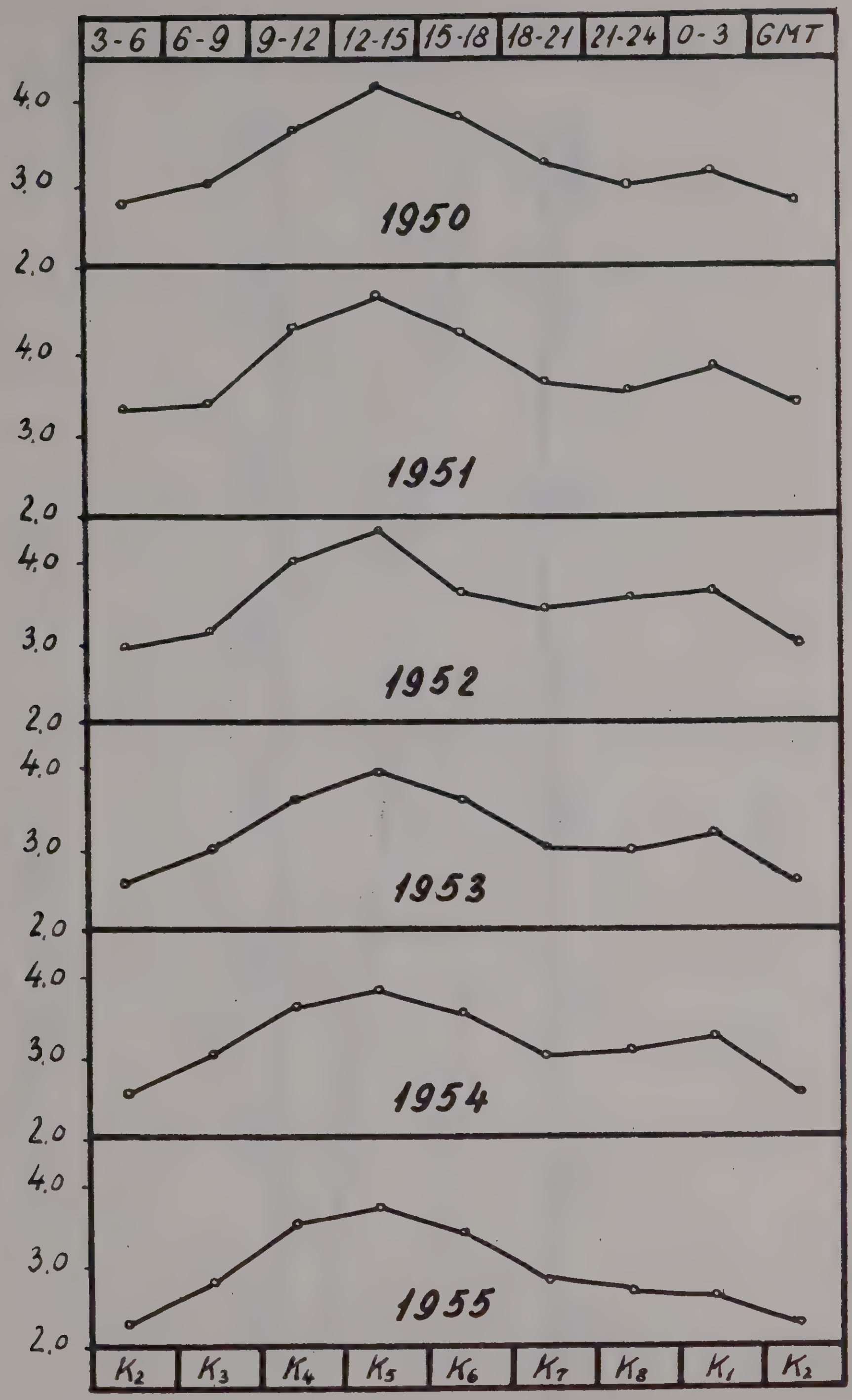

Fig. 12b. Diurnal distributions of mean magnetic activity, equinoxes 1950-55.

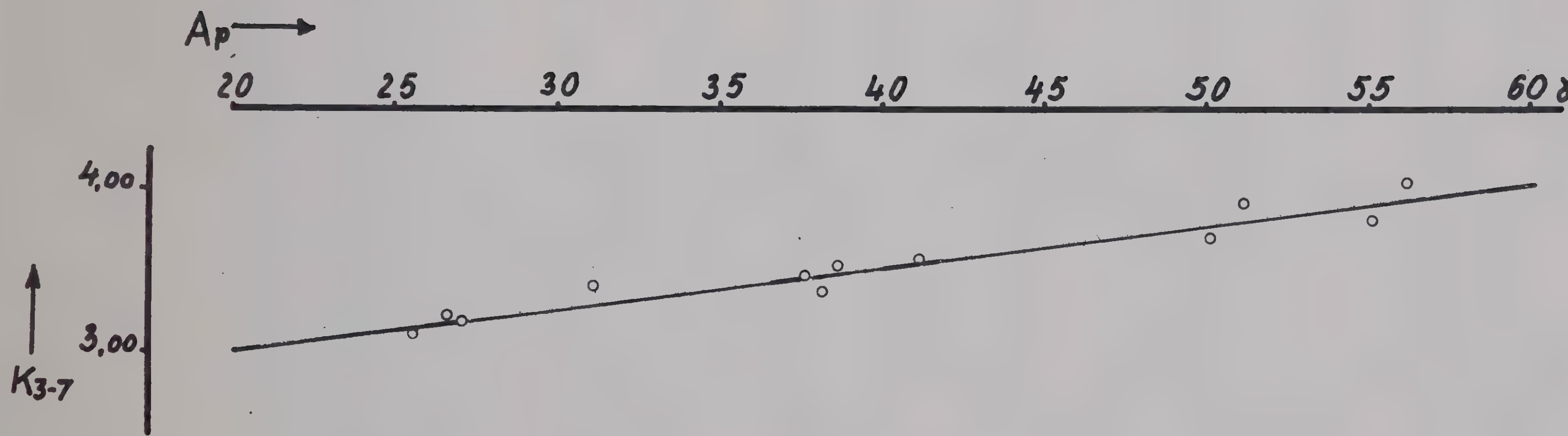

Fig. 13. K_{3-7} (∼J) vs. A_p, equinox.

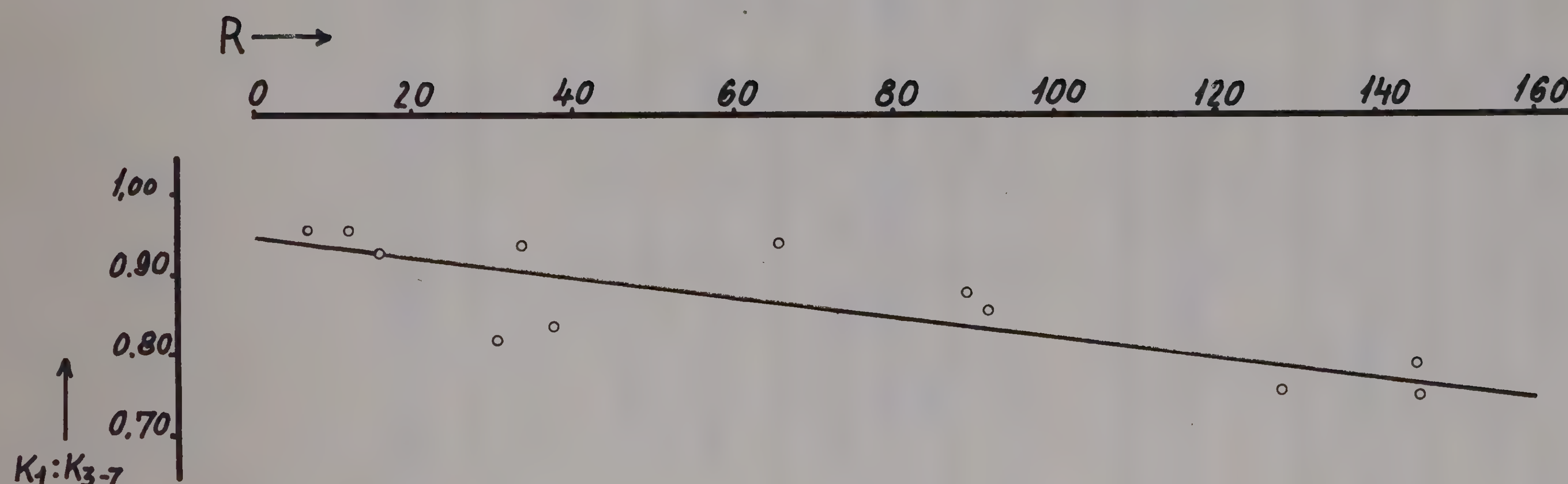

Fig. 14. $K_1 : K_{3-7}$ vs. R, equinox.

5.

In fig. 15 the variation through the sunspot cycle of N_T for the equinoxes has been plotted together with the sunspot curve and the corresponding curves for winter and summer. It is seen from the figure that for all seasons N_T varies in phase opposite to R, possibly, however, with its maximum about one year before the sunspot minimum. N_T crosses (measured in this manner) its average value about one year after the sunspot minima (spring 1945 and spring 1955) and half-away between these times (spring 1950).

The variation of N_T is naturally explained if it is assumed that the northern boundary of the disturbance of type N is moving northwards during decreasing solar activity.

The division of the winters in fig. 6 into two groups shows that N_T for the same value of A_p is largest in winters near sunspot minimum; this is in accordance with that the maximumzone of the N-activity is then nearest to Godhavn.

The shifting of the northern boundary of the N-activity is not a consequence of increased planetaric disturbance near sunspot maximum; the shifting follows the change in the sunspot number R, and one and the same value of the planetaric activity A_p results in different activities N_T at Godhavn in different parts of the sunspot cycle.

6.

Tromholt (1882) showed, by analysis of observations made by Kleinschmidt, that the frequency of auroras at Godthåb (64°.2 N, 308°.6; ϕ_m=74°.8) varies opposite in

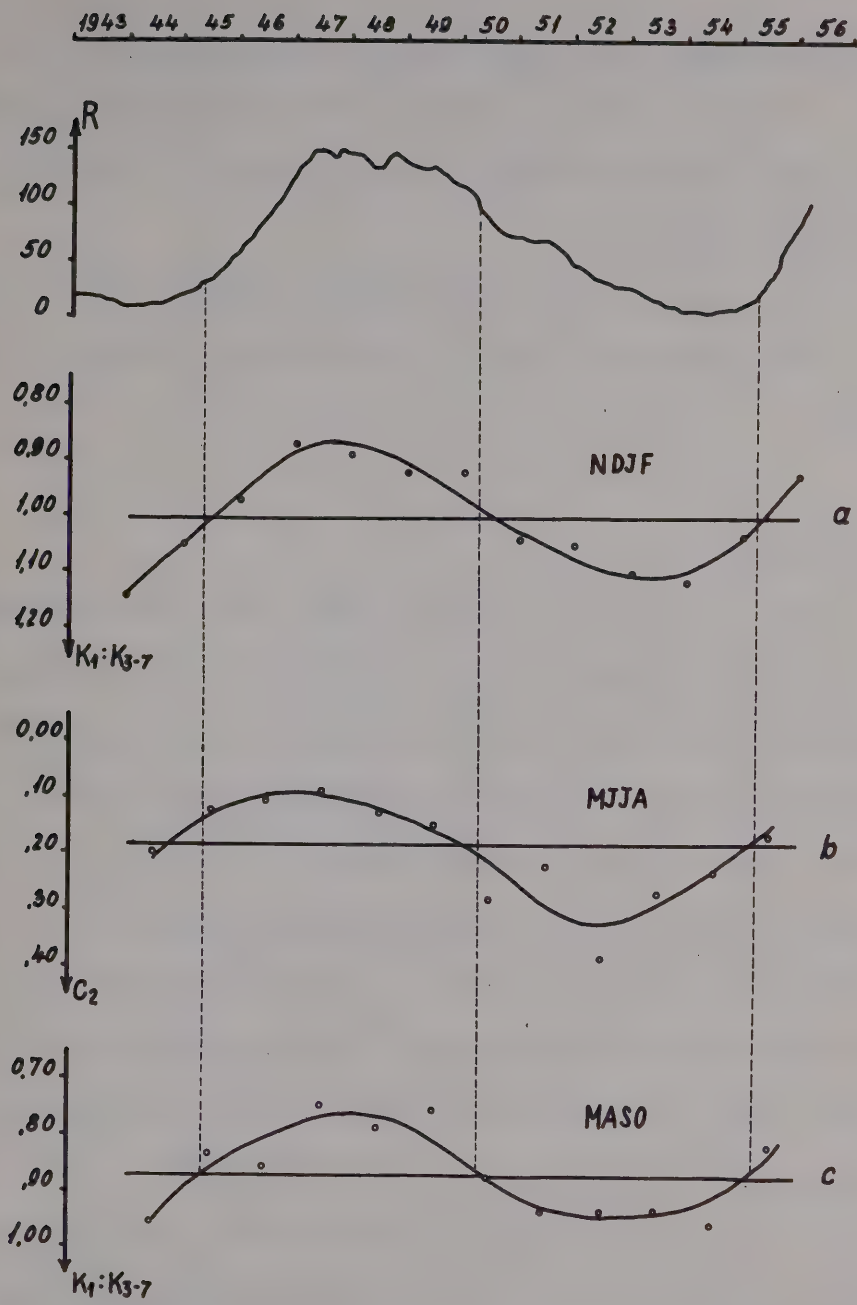

Fig. 15. Variation of N_T through the sunspot cycle.

phase to R and consequently to the auroral frequency on the equatorial side of the auroral zone. As Godthaab is situated on the inner (polar) side of this zone. Tromholt explained the found law by assuming that the auroral zone moves in a north-south-direction during the sunspot cycle.

As N_T as mentioned is accompanied by brilliant auroras, the found variations of N_T seem to confirm Tromholt's hypothesis on the shifting during the sunspot cycle of the auroral ring.

7. Yearly distribution.

To illustrate the yearly variation of the activity the median of the monthly means of K for the eight three-hour-intervals of each month of the year has in table 6 been shown for the eleven-year period 1944-54. The corresponding monthly median-curves are collected in fig. 16. It is directly seen that the J-activity decreases from summer through equinox to winter, whereas the relative influence of N_T is largest in the wintermonths.

The variation of J has been examined by harmonic analysis of K_{3-7}. (The last column of table 6 shows that this quantity will be practically unaltered, if the period 1945-55 is studied). The result is shown in table 7. If the median K-value of the month at the analysis is centered in the middle of the month ($15^d 5$), it is found that the maximum of the first harmonic falls on June 21, i. e. at summer solstice.

Table 7 further shows the result of a harmonic analysis of the monthly means of the declination of the sun at 12^h GMT. The maximum occurs simultaneusly with that of the J-activity, so that also the yearly variation of the J-activity is a function of the position of the sun.

Table 6. Monthly means of K, median 1944-54.

GMT / Month	0 - 3 K_1	3 - 6 K_2	6 - 9 K_3	9 - 12 K_4	12 - 15 K_5	15 - 18 K_6	18 - 21 K_7	21 - 24 K_8	K_{3-7}	K_{3-7} 1945-55
Jan.	3,00	2,77	2,64	2,97	3,10	3,00	2,57	2,42	2,86	2,83
Febr.	2,97	2,50	2,54	3,10	3,57	3,41	2,79	2,54	3,08	3,12
March	3,42	2,84	2,84	3,70	4,06	3,78	3,22	3,13	3,52	3,49
April	2,93	2,43	3,00	3,83	4,37	4,13	3,36	3,03	3,74	3,75
May	3,03	2,74	3,21	4,10	4,58	4,35	3,58	3,39	3,96	3,96
June	2,82	2,87	3,43	4,37	4,70	4,50	3,70	3,20	4,14	4,14
July	3,13	2,84	3,23	4,24	4,64	4,50	3,70	3,32	4,06	4,06
August	3,14	2,81	3,06	3,99	4,48	4,13	3,45	3,23	3,82	3,82
September	3,34	2,87	3,20	3,76	4,10	3,80	3,23	3,47	3,60	3,60
October	2,94	2,50	2,84	3,44	3,87	3,60	2,90	2,68	3,33	3,33
November	2,76	2,40	2,64	3,10	3,27	3,00	2,43	2,40	2,89	2,89
December	2,94	2,52	2,52	2,94	2,87	2,70	2,29	2,45	2,66	2,62

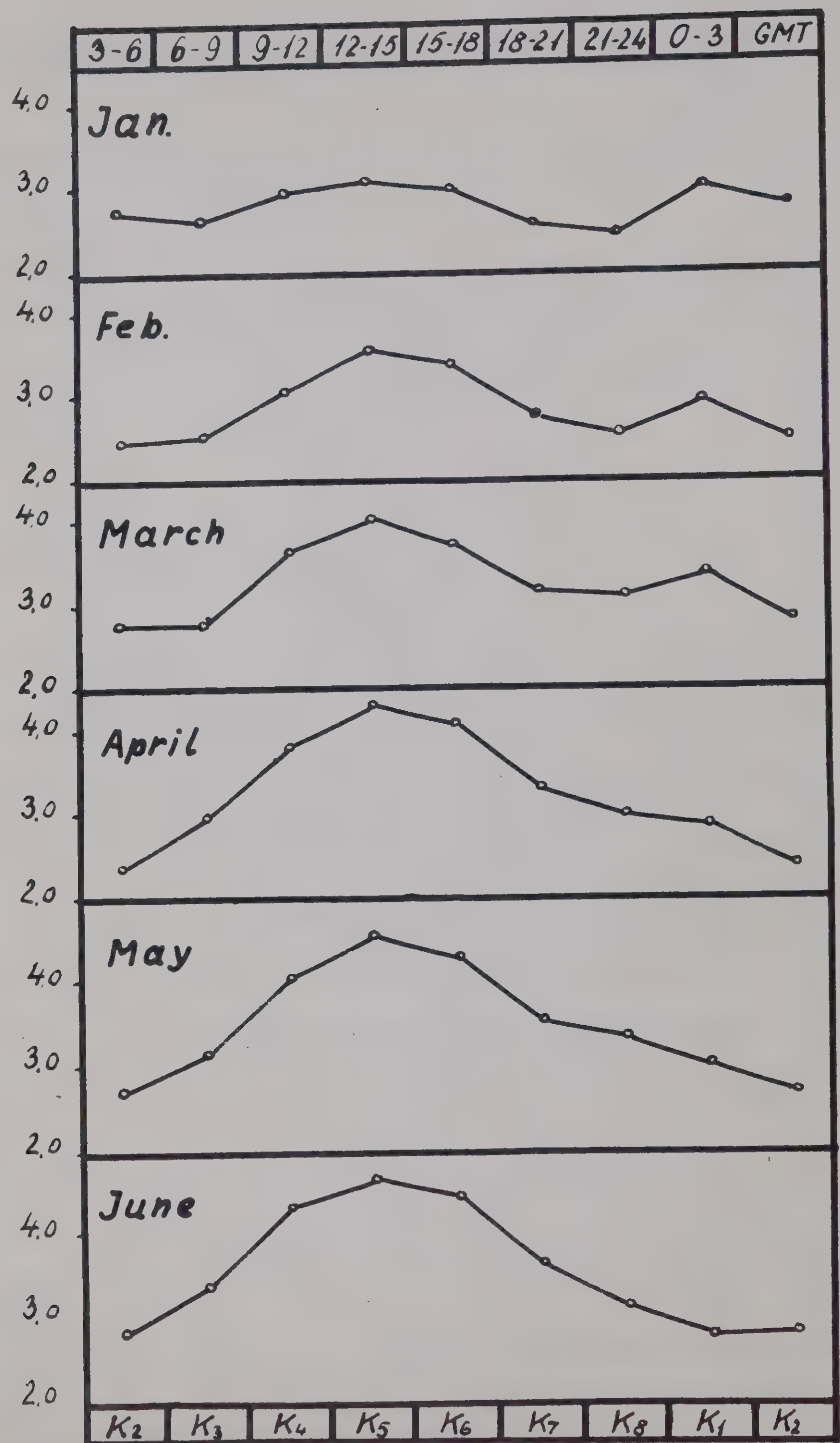

Fig. 16a. Diurnal distributions of magnetic activity. Medians for the years 1944-54 of monthly mean values of K.

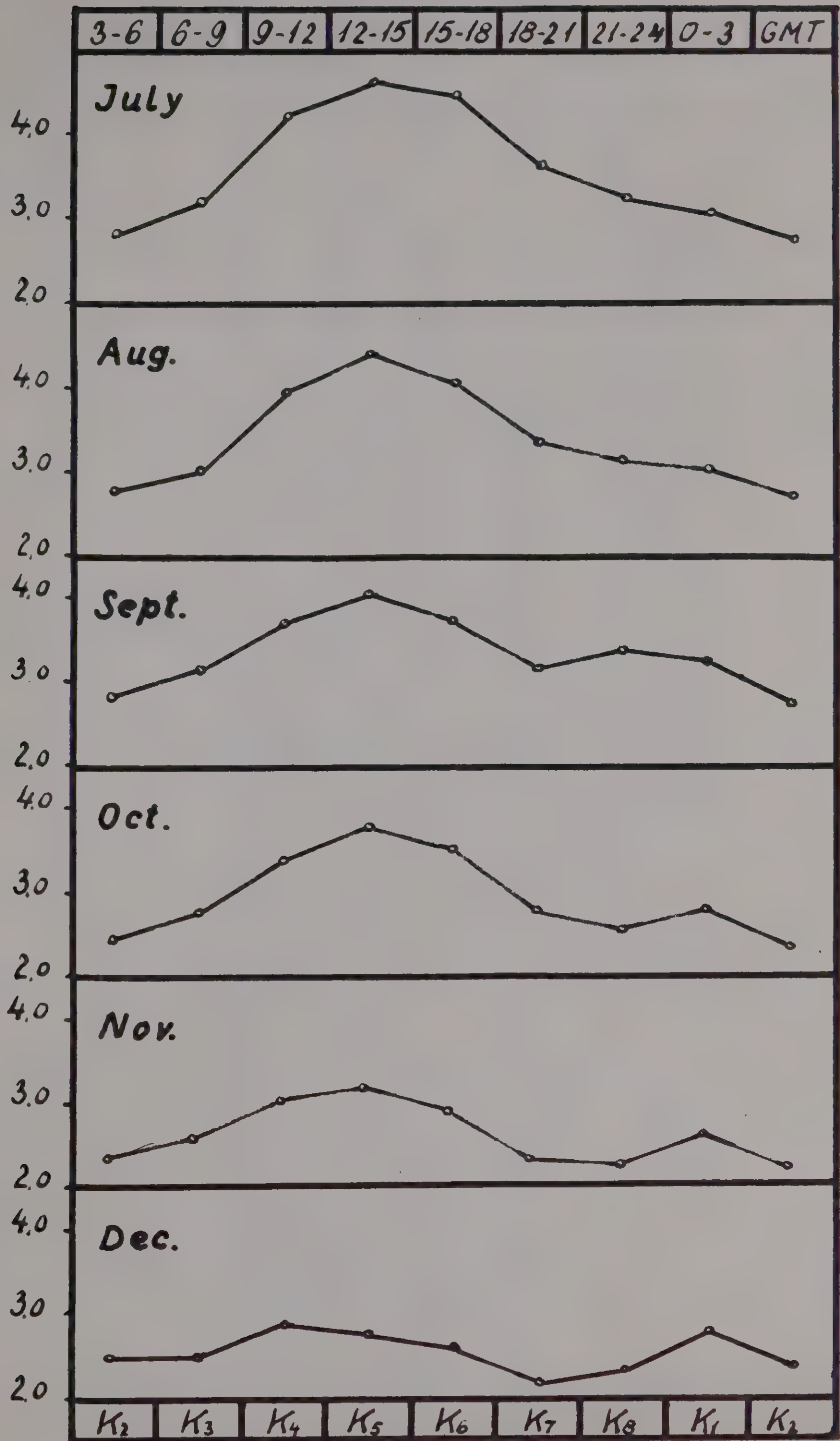

Fig. 16b. Diurnal distributions of magnetic activity. Medians for the years 1944-54 of monthly mean values of K.

Table 7. Results of harmonic analysis of yearly J-distribution and sun's declination.

	mean	c_1	maximum date	c_2	maximum dates	
Monthly median K_{3-7} 1944-55	3,47	0,66	June $21,^{d}1$	0,07	March 22	Sept. 21
Sun's declination 12^h GMT monthly mean	+ 0°19!4	23°0	June $21,^{d}1$	0°24	March 19	Sept. 18

The second harmonics of the J-activity and the declination are in phase too, but c_2 of the activity is larger than should be expected from the dependence on the declination alone.

As mentioned N_T is largest in winter. The correspondance with auroras makes it reasonable to assume that N_T has a maximum at winter solstice. It is hardly possible from the K-indices to find a reliable method for the determination of the absolute yearly variation, and it has therefore been found more correct to postpone this determination till a planned study of the polar magnetic storms.

8. Magnetic activity prior to the years 1944-55.

For the period from the establishment of the observatory at Godhavn in 1926 to 1943 K-indices are only available for a few years. In order to examine whether the found variations with the sunspot period are also present before 1944 other, somewhat less suitable, criteria of magnetic activity are therefore studied.

1° N_T. For the examination of the variation of N_T with R the international index C, computed for the period December 1 - January 13, when the sun is under the horizon at Godhavn, has in fig. 17a been plotted together with R for the years 1926-50 (the plotted value of C is the running average for three consecutive winters). In the mentioned part of the year C is mainly a measure of N_T. The same is the case with the mean daily range of H for December, which, smoothed in the same manner as C, has been plotted in fig. 17c, for the years 1932-50 (daily ranges are not available for the years prior to 1932).

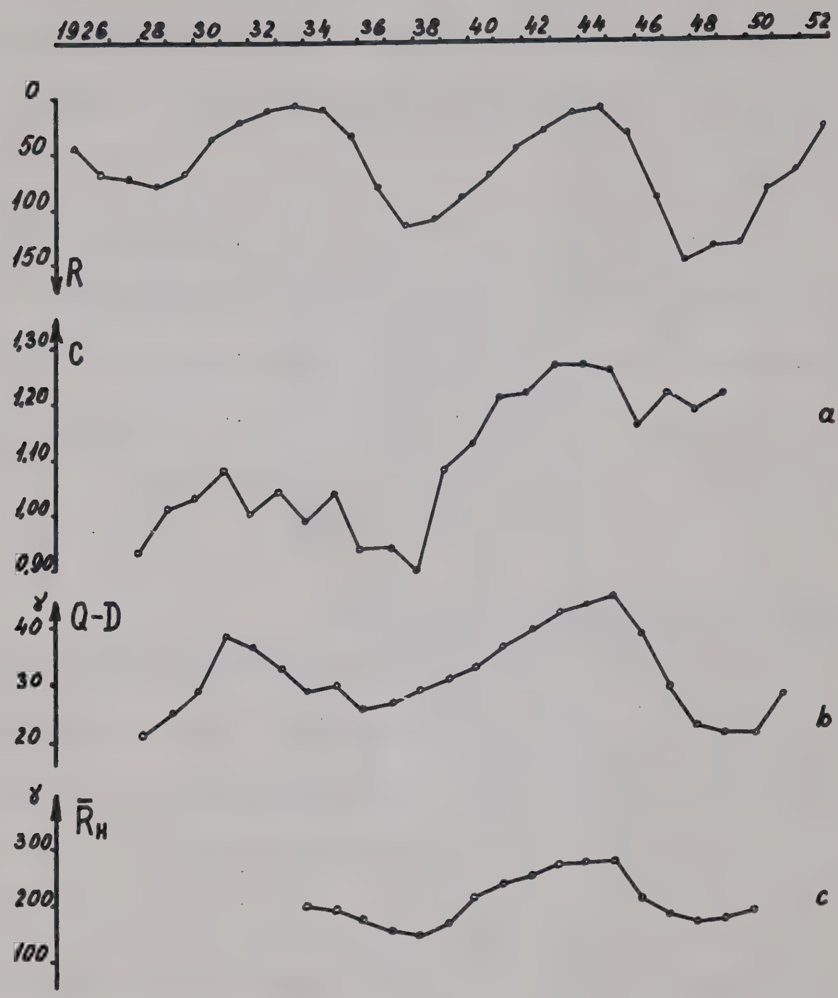

Fig. 17. Variation through the period 1925-52 of the sunspot number R compared with a) average index C (Godhavn) for Dec. 1 - Jan. 13, b) differences of daily means of H, international quiet minus disturbed days, December, c) average daily range of H, R_H, December.

As the PMS causes a depression of H, also the differences between the daily means of H for the international quiet and disturbed days, Q÷D, in December are mainly influenced by N_T. Running mean values of (Q÷D) for three consequtive years have been plotted in fig. 17b.

Fig. 17 shows that all the indices mentioned vary in opposite phase to R; hence it is concluded that N_T varies in opposite phase to R in the whole period 1926-55.

In December and January the diurnal inequality of H is negligible. The majority of the daily ranges of H in these months is therefore mainly caused by PMS's, so that the different frequencies of these at sunspot maximum and minimum are reflected in the different distributions of the magnitudes of the daily ranges of H. Fig. 18 shows the cumulative frequency-curves for the daily ranges of H for December and January for sunspot numbers $R > 80$ and $R < 40$ respectively. The period examined is 1932-50. The sympolygon for the sunspot minimum-years is markedly displaced against greater ranges; thus of all daily ranges 11% are larger than 500 γ, 8% larger than 600γ, 6% larger than 700 γ and 1% larger than 1000γ. The corresponding percentages for the sunspot maximum-years are 1%, 1%, 0%, 0%.

2° J. In summer the international index C is mainly expressive of the J-activity. Running mean values of C for three consecutive summers of the years 1926-51 have in fig. 19 been plotted together with A_p (smoothed) and R. C varies in phase with these parameters.

9. Conclusion.

The polar magnetic activity J is dependent on the position of the sun. The yearly variation is a single wave with its maximum at summer solstice, and the daily variation is a single wave with maximum at magnetic noon. The daily mean of J increases with increasing A_p, whereas the amplitude of the daily variation follows the sunspot number R.

The zone of maximum magnetic activity of class N, connected with and presumably identical with the auroral zone, oscillates north- and southwards, so that the zone is nearest to the pole in the years immediately before the sunspot minimum.

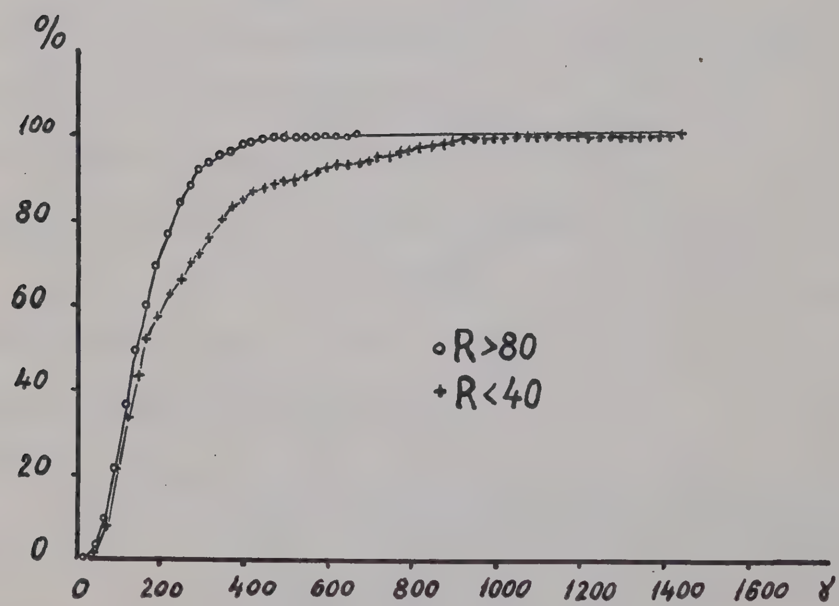

Fig. 18. Cumulative frequency-curves, daily ranges of H, December and January, period 1932-50.

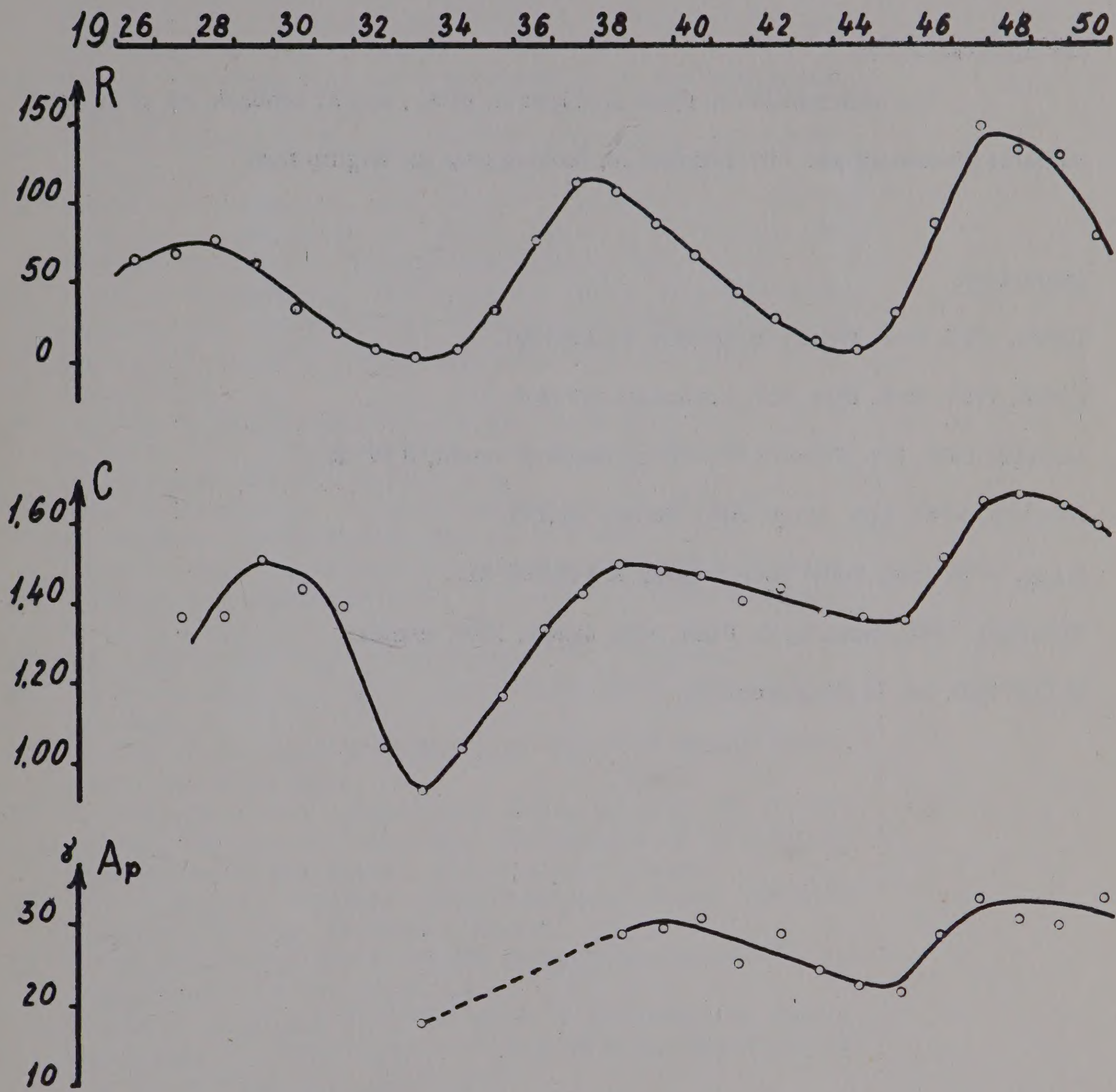

Fig. 19. Variation through the period 1926-50 of sunspot number R compared with average index C (Godhavn), summer, and planetaric index of activity, A_p.

Acknowledgements.

The author wishes to thank J. Olsen,M. of S. , and A. Lundbak, M. of S. for valuable discussions and Mrs. Lundbak for looking over the English text.

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